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HYPOLIMNETIC OXYGEN: DATA COLLECTION STRATEGIES FOR USE IN PREDICTIVE MODELS

DATA COLLECTION STRATEGIES FOR PREDICTIVE MODELS

Hypolimnetic oxygen concentrations are a key element of habitat quality for many cold-water species. These include fish such as lake trout and whitefish as well as many invertebrates including Copepods and Mysis that are important food for fish. Oxygen concentration profiles are typically measured at the deepest location in the lake, usually on a monthly basis throughout the open water season. These types of data are difficult to interpret because concentrations change both spatially and temporally in a specific year and also tend to show considerable inter-annual variation.

One method of addressing a great deal of this variation is to examine only end-of-summer or end-of-stratification oxygen profiles. This eliminates the need to evaluate seasonal changes in the profile and concentrates on the "worst case" profiles at the time of year when oxygen concentrations in the hypolimnion are at the open-water minimum. When attempting to characterize lakes in this manner, it is preferable to use average profiles which are derived from several years of data to offset the effects of inter-annual variation. This approach will allow the description of average conditions in a lake's hypolimnion at the end of summer (early in September) and compare between-lake differences under similar conditions.

In 1992, a model* which predicts steady state, end-of-summer oxygen profiles for small oligotrophic lakes was developed as an additional component of the ministry's Lakeshore Capacity Model (LCM). The oxygen model uses lake morphometry and epilimnetic phosphorus concentration to predict end-of-summer oxygen concentrations of each stratum in the hypolimnion. An example is shown in Fig. 1. The model requires total phosphorus (TP) as one of its parameters, and can therefore be used to predict the effects of shoreline development on hypolimnetic oxygen.

Recent efforts to validate the model indicate that it will predict end-of-summer profiles for lakes with a broader range of size and trophic status than those that were used to formulate the model.

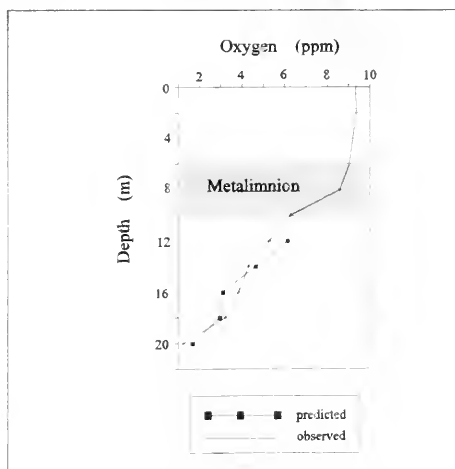

Figure 1 Measured and predicted end-of summer oxygen profiles for Nunukani Lake. The model does not predict epilimnetic or metalimnetic oxygen concentrations.

Morphometry plays a major role in determining hypolimnetic oxygen concentrations. With the model, oxygen profiles can be predicted using as a minimal, a lake morphometric map

and a modelled TP value (if no measured TP data exist). It is preferable to use long-term mean spring overturn TP.

To use the model for predicting the effects of changes in trophic status, it is preferable to average several years of oxygen profiles from the time period spanning two weeks either side of the first week in September. The model is then used to predict how changes in TP concentrations would effect the measured (not modelled) long-term average profile. This approach maintains the unique shape and magnitude of the lake's end-of-summer oxygen profile. Operation of the model is straightforward and it can be obtained as a spread sheet from the Dorset Research Centre.

From a data collection standpoint, this approach to oxygen monitoring suggests that field crews concentrate on the collection of end-of-summer profiles specifically between August 15 and September 15. Temperature profiles should also be collected to determine hypolimnetic boundaries. Data bases, for example, could benefit more from the collection of oxygen profiles from several different lakes circa early September than from a series of monthly observations from the same lake over the course of a summer. In other words, in this case, a survey approach would be more useful than a monitoring program.

DETERMINING HYPOLIMNETIC VOLUME-WEIGHTED OXYGEN CONCENTRATION

There are several methods used to quantify cold-water fish species habitat based on oxygen concentrations. For lake trout, optimal habitat has been described as having greater than 6 mg L^{-1} oxygen at less than 10° C. Usable habitat has expanded boundaries at greater than 4 mg L^{-1} oxygen and less than 15°C. These guidelines can be used to generate habitat "volumes". However, these may be difficult to interpret since similar "volumes" between lakes may represent different proportions of total lake volumes.

The proposed use of end-of-summer, volume-weighted hypolimnetic oxygen concentrations to define lake trout habitat would eliminate many of these problems. Lakes with large volumes of oxygenated water would not have their average greatly affected by small volumes of depleted water near the bottom. Lakes with small and enriched hypolimnia would be affected to a greater degree by increased depletion in bottom waters. It is suggested for lake trout that these values remain above 7 mg L^{-1} oxygen.

Calculating volume-weighted hypolimnetic oxygen requires morphometric data and at least one end-of-summer oxygen profile (Aug 15 - Sept 15). Ideally, oxygen profiles from several years would be used to reflect long-term average conditions. Area and depth information from morphometric maps should first be converted to ha and m if originally in acres and feet. This will yield contour areas in ha for uneven numbers of m but these can be converted to 1 or 2 m contour areas by one of two methods:

1. Metres and ha are plotted and the individual areas for each stratum are simply read from the axis of the graph.
2. Individual pairs of adjacent points in ha and m are used to interpolate areas for the intervals that fall within the depth range spanned by the pair of points. This can be done through simple linear interpolation or by doing a linear regression on two pairs of points. However, it is important to note that entire sets of hypolimnetic depth/area data cannot be regressed as a single group of numbers because the relationship is almost always curvilinear. Individual contour areas are then converted to volumes by the formula:

$$V = \frac{m}{3}\left(A_t + A_b + \sqrt{A_t * A_b}\right)$$

where **V** is volume in $m^3 \times 10^4$
A_t is the area in ha of the top of the stratum
A_b is the area in ha of the bottom of the stratum
and **m** is the depth of the stratum in m

The volume of each stratum of the hypolimnion is then expressed as a fraction of the total hypolimnetic volume and multiplied by the oxygen concentration observed for that stratum. These individual concentrations are summed to yield volume-weighted average oxygen as shown in the example below.

Stratum	Volume (10^3m^3)	A-Volume as fraction of total Volume	B-Dissolved oxygen (mg L^{-1})	A * B
14-16m	1500	0.49	10.0	4.9
16-18m	1000	0.33	8.0	2.6
18-20m	400	0.13	6.0	0.78
20-22m	150	0.05	1.0	0.05
Total of A*B is volume weighted oxygen concentration				**8.33**

It should be noted that volume-weighted oxygen concentration calculations yield a single number which may respond differently from lake to lake to changes in trophic status. The number should be interpreted together with other physical and chemical information relating to the lake in question. However, it is a simple and useful measure related directly to lake trout habitat.

*Footnote: Details of the oxygen model have been published in: Molot, L.A., P.J. Dillon, B.J. Clark, and B.P. Neary. 1992. Predicting end-of-summer oxygen profiles in stratified lakes. Can. J. Fish. Aquat. Sci. 49:2363-2372.

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